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# Art. VI.—*The Occurrence and Development of Cervical Ribs in Man and some of the Mammals that have abandoned Quadrupedal Progression.*

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Cervical ribs have acquired such a prominent place in modern surgery that practical as well as scientific reasons demand that the causes controlling their formation should be investigated. The observations and deductions that are put forth in this paper are the outcome of my enquiry into such causes, and they form an extension of the abstract published in the Australian Medical Journal, August 19, 1911.

The endeavour has been made to discover not only the influences that cause the development of cervical ribs, but also the hostile conditions that suppress rib growth and destroy rib structure.

It will be shown that cervical ribs develop in the human neck because the lungs have migrated towards, and encroached on, the neck; and, from the conditions associated with general rib development, the deduction is drawn that cervical ribs form in the human neck in response to impulses that are generated in the organism which has been and is being excited by the presence of lung in the neck.

## Classification of the Principal Stages in the Evolution of Cervical Ribs.

(1) The primary development of rib-structure in the neck-area.

(2) The suppression of neck rib-structure.

(3) The secondary development of cervical ribs.

The primary development of ribs in the neck-area is illustrated by the structure of fish.

The suppression of cervical ribs can be studied in the following structures:—

(a) The cervical rib-stumps of crocodiles.

(b) Costal processes as they occur in the mammalian neck.

Neck rib suppression is further evidenced by the absence of costal processes from the seventh cervical vertebra of the quadrupedal mammals. The absence of these costal processes shows that the rib-structure which is associated with the seventh neck bone may, under the influence of the neck flexion that occurs in the quadrupedal mammals, suffer extinction.

The development of cervical ribs in the mammalian neck may be either partial or complete.

(a) Partial in the short cervical ribs that do not reach the sternum, as seen in dugongs and man.

(b) Complete in the sternal cervical ribs of the manatee and in the occasional sternal cervical ribs of man.

## Function of Ribs.

Ribs are stiff and resilient. The uses to which these qualities are put by the animal economy constitute the functions of ribs.

Fish-ribs stiffen the body and protect viscera, but they possess no respiratory function.

In the chameleons, the sphenodon, and other lizards possessing a low grade of neck development, cervical ribs are continuous with the ribs of the body-cavity, their function being to protect viscera and to assist respiration. In snakes the cervical ribs are greatly developed and their function is locomotory. The cervical rib-stumps of the crocodile afford muscular attachments, and they confer some degree of rigidity upon the neck.

The costal processes of mammals are too small to interfere with the freedom of the movement of the neck, and they serve merely for muscular attachments. The main function of the thoracic ribs is associated with respiration, and the rib development that occasionally takes place in the mammalian neck is also intimately associated with the lungs. Therefore

## Cervical Ribs of Mammals are of Respiratory Function.

Cervical ribs have been variously described:—Keen, in 1907, referred to them as "congenital anomalies"; Andrews, in Keen's Surgery, calls them "deformities." Purves Stewart records that Oppenheim regards cervical ribs in the human neck as the "stigmata of degeneration." Here and there cervical ribs are regarded as examples of atavism, but the majority of medical men regard them as vestiges.

The term "congenital anomaly" can only be used in a very restricted sense because science cannot regard any natural condition as anomalous. The word "deformity" conveys no idea as to what causes the development of cervical ribs. The expression "stigmata of

degeneration" throws no light on the cause of cervical ribs, but as the development of cervical ribs in mammals is associated with degenerative changes in the neck, the term is useful.

Considerable confusion seems to exist about vestiges and cervical ribs. It is as well to preface the remarks on this subject by quotations from Morris's Human Anatomy and Arthur Keith's Human Embryology and Morphology.

Morris says:—"The costo-transverse foramen is very characteristic of a cervical vertebra. It is bounded internally by the pedicle, posteriorly by the transverse process, which corresponds to the transverse process of a thoracic vertebra, anteriorly by the costal process, which corresponds to the rib in the thoracic vertebra, and externally by the costo-transverse lamella.

"The transverse process (of the seventh cervical vertebra) is massive; the costal element of the process is very small, but, on the other hand, the posterior or vertebral part of the process is large, and becoming more like the transverse process of a dorsal vertebra. The costo-transverse foramen is the smallest of the series and may be absent. Occasionally the costal process is segmented off and constitutes a cervical rib."

Keith says:—"Vestigial Ribs: Although the ribs are only fully developed in the dorsal region, yet a representative, a costal element, is present in every vertebra."

"The costal process of the seventh cervical, usually represented by a mere vestige, may develop into a rudimentary or even a fully formed rib."

It is difficult to accept this teaching of Keith, because it contains an error somewhat akin to the exploded idea that cranial bones are modified vertebrae, for he confuses the costal process, which is a reduced rib, with the costal rudiment, from which all ribs must develop.

The formation of costal processes is shown in the monotremes; there, in the *Platypus*, the rib-stumps are separated from the vertebrae by joints, but in the *Echidna* these joints are more or less indistinct and the rib tissue is becoming confluent with the neck bones. In the higher mammals these joints have entirely disappeared and the suppressed ribs remain as costal processes or rib vestiges. Costal processes are vestiges of ribs because they mark the remains of pre-existing cervical ribs. Mammalian cervical ribs are developments because they appear in positions which have been occupied either by ribs that have become extinct, or by costal processes, ribs that have become vestigial. Cervical ribs are developed ribs, and the development varies from slight to full. A developing, or a developed, structure is not a vestige, nor is a vestige a rudiment, nor

is the costal process the costal rudiment. The term "costal element" that is frequently used, can refer to but one thing, and that one thing is the costal rudiment, from which all rib tissue, suppressed and developed, must arise. Costal processes express suppression, by hostile movement, of rib tissue; cervical ribs express rib development over lung tissue that has migrated into the neck.

If cervical ribs be developed costal processes, as Keith claims, cervical ribs should be devoid of joints and appear as buttresses of bone fused with the transverse process and body of the vertebra, even when quite small cervical ribs are jointed. The difference between costal processes (vestigial ribs) and cervical ribs is the difference between suppression and development. The greatest likeness that can be claimed between them is they may both arise from a rib rudiment, which by no means makes them one and the same thing.

## Atavism.

In order that the association of atavism with cervical ribs may be reviewed, it is necessary to pass back through the mammals where cervical ribs were absent, through the monotremes and later reptiles where cervical ribs occur, back to the early reptiles, where cervical ribs had persisted from the fish-type; and then to show that the germ plasm as it passed through successive stages of evolution has retained the hereditary power to form cervical ribs, and that this power, though possessed, has been held in subjection until quadrupedal progression has been abandoned and the adoption of some other form of progression has made it possible for cervical ribs to form. This much is necessary to the belief in atavism in spite of latter-day criticism, with its pruned version as to what atavism is. The interpretation of the theory of atavism has been altered and contracted from the widest limits to the narrowest confines. To many present-day pathologists the word atavism connotes:—"The appearance in an individual of normal or pathological characters which are wanting in the parents, but were present in the grandparents or great-grandparents." (Ziegler.)

These ideas are embodied in the Mendelian law, and if the word atavism is only to be thus used, it should become obsolete, as it leads only to confusion.

As an example of atavism, Bland-Sutton wrote:—"The attainment of a functional condition by parts normally suppressed is well illustrated in the case of man by supernumerary ribs."

When going into detail, Sutton displays unfamiliarity with the neck bones, for he says:—"Supernumerary ribs attached to the lumbar vertebrae are more instructive than those in the neck."

He is also in error when he says:—"In many birds and reptiles all the cervical vertebrae bear ribs," whereas many birds, particularly ostriches, show large vestigial neck ribs. Owen in 1866 had correctly written:—"In the cervical vertebrae of birds the pleurapophysis, if present, is confluent with the neural arch."

Gegenbaur refused to accept the old ideas of atavism and laid it down that:—"Atavistic parts do not belong to forms palaeontologically or systematically far distant."

Sutton, who accepted Gegenbaur's restrictions, grouped atavistic phenomena into two classes:—(1) "The attainment of functional condition by structure normally suppressed." (2) "Reversion of organs and tissues to an original type."

Although Darwin had no difficulty in understanding the extinction of species, he realised that he was unable to understand the extinction of organs and structures. The following quotations from Darwin's writings bear out this point:—"It is most difficult always to remember that the increase of every creature is constantly being checked by unperceived hostile agencies, and that these agencies are amply sufficient to cause rarity and finally extinction."

"There remains, however, this difficulty after an organ has ceased being used, and becomes in consequence much reduced, how can it be still further reduced in size until the merest vestige is left; and how can it be finally quite obliterated? It is scarcely possible that disuse can go on producing any further effect after the organ has once been rendered functionless. Some additional explanation is here requisite which I cannot give."

The theory of atavism does not fit the evolution of cervical ribs; the old idea takes us back to the early lizards and fish, the modern idea to the quadrupedal mammals, and the new idea is distinctly Mendelism.

The destruction of neck ribs can be traced from the fish through the reptiles and monotremes until in the mammals they become small and confluent with the neck bones. From the quadrupedal mammals through some of those mammals that have abandoned quadrupedal gait, notably man and sirenia, cervical rib development may be traced from small undeveloped cervical ribs that appear only occasionally in the dugong, to fully formed cervical ribs that occur constantly in the manatee.

The point of greatest interest in relation to mammalian cervical ribs is the seventh cervical vertebra; a careful study of this bone shows that ribs undergo not only suppression, but that they also undergo extinction, for when the seventh cervical vertebra is without costal processes, it is evident that the rib vestiges have disappeared and that the ribs, which in an earlier stage of evolution belonged to this bone, have become extinct.

It seems a process of narrow reasoning which admits the origin of new species, but refuses to admit that new structures may be evolved. The denial of the appearance of new structures seems to be the basis of the theory of atavism.

Where ribs develop in sites that have been previously occupied by vestiges of extinct ribs, new rib-forming impulses have arisen which are of a different character to those impulses that have suppressed neck-ribs and formed rib-vestiges, or to those that have brought about the extinction of rib.

Darwin did not fully grasp the relationship that exists between organs, structures and species. It is apparent that structures and organs form the parts of the species; and it follows that that which applies to the whole must apply to the part. Species are admitted to suffer extinction through hostile influences, and therefore it must also be admitted that structures and organs may likewise suffer extinction by the same means.

Bland-Sutton wrote:—"Much that is fanciful and speculative is mixed up with the subject of atavism," and a study of neck ribs compels the endorsement of this remark, for it is a fanciful idea that regards mammalian cervical ribs as atavistic to the ribs in the neck area of fish.

Mammalian cervical ribs develop in association with respiration, fish ribs are unassociated with lung, therefore mammalian neck ribs and ribs in the neck-area of fish are not teleologically related, for they are each utilised for a different purpose. It will be shown that cervical ribs are late developments in the mammalian neck, which development is due to the impulses that are occasioned by the encroachment of lung into the neck.

The costo-transverse foramen is absent from the seventh vertebra in most quadrupedal mammals that have well defined neck curves; and usually associated with the absence of this foramen is the lack of costal processes. The absence of costal processes from this bone would appear to be determined by the fact that their presence would hamper the range of what in quadrupedal animals is an extensive neck movement occurring in this position. The seventh neck bone of such animals has been submitted to extinction of its rib vestiges by the hostile effect of neck flexion upon a thoracic base that has been made firm by the lateral pressure of the weight of the body. Occasionally in true quadrupeds, the costal processes on the seventh cervical vertebra are not suppressed on both sides. We have found this abnormality in the racehorse "Traquair," and Dr. Dodd, of the Sydney University, writes me that he also has a specimen of the same abnormality, that is, the costal process of the sixth neck bone is suppressed on the same side as it is developed on the seventh. Sisson,

Veterinary Anatomy, page 33, records similar abnormalities. This change of position of the costal process is clearly compensatory, and it is probably due to the impulses that cause these horses to lead off the gallop from the same foot.

The extinction of the costal processes from the seventh vertebra by the flexion of the neck seems to clear up the point which puzzled Darwin, how structure may become extinct. The costal processes of the seventh neck bone disappear before hostile conditions that are sufficiently hostile to suppress them to extinction. We have evidence that the costal processes of the seventh vertebra are suppressed to extinction by the flexion of the neck; and this fact shows a reason for the extinction of definite structure and it goes to prove that structures and species are controlled by the same law. If it be admitted that species and structures are controlled by the same law, it follows that cervical ribs in mammals represent a new type of rib situated in the same positions as ribs that have suffered extinction; and, therefore, they are not atavistic structures but new developments.

If it be admitted that mammalian cervical ribs are atavisms, then it must be admitted that extinction of rib-structure is a throw-back to the invertebrates.

A brief account of some of the hostile influences that have assailed cervical ribs, reduced them to vestiges, and finally caused their extinction will be dealt with in the body of this paper.

## Impulses.

Smith-Woodward writes thus (Ann. Nat. Hist. xviii., 1906, page 312):—

"Throughout the evolution of the organic world there has been a succession of impulses, each introducing not only a higher state of life, but also fixing some essential characters that have been variable in the grade immediately below."

From this quotation it does not seem clear what an impulse is. Does it represent the action of environment on the organism, or the reaction of living tissues to external conditions from which results the generation of impulses? These two things are very different; one ignores the re-action of tissues and the other regards it as an essential factor. In dealing with neck tissues it seems impossible to ignore the biological factor and to explain the evolution of the neck by physical conditions alone. For instance, there is a general belief that "continued pressure causes atrophy, and intermittent pressure hypertrophy," and yet the necks of porpoises and whales that are submitted to intermittent pressure show atrophic changes. These neck tissues react to the impulses which the biological factor in reaction with external conditions generates.

In this paper it will be assumed that the evolution of the neck is controlled by impulses that are generated by the reaction of the tissues to external chemical and physical conditions. These impulses determine change and stability in animal tissues and under their influence it will be shown that fixed-type may be destroyed and new tissues arise.

## The Evolution of the Neck.

Mammalian neck evolution may be studied in the *Schnapper*, *Ceratodus*, *Trachysaurus rugosus*, *Varanus varius*, *Crocodilia*, *Platypus*, *Echidna* and *Mammalia*.

In many fish dorsal and ventral ribs occur; the former extend between the muscles and the latter stiffen the walls of the body-cavity. Some seem to use the words dorsal and ventral to the parts of a mammalian rib, the rib proper being termed the dorsal rib and the costal cartilage the ventral; this use is still more commonly adopted in describing avian ribs. There also seems to be an ill-defined tendency on the part of some writers to assign to vertebrae the power of laying down ribs. As all the bones of the body are formed in response to impulses it follows that vertebrae and ribs come alike under the influence of the impulse. As the body requires new bone, fresh centres of ossification undoubtedly develop; and, as movement becomes necessary, joints appear.

In the schnapper and haddock the heart occupies a position in the gill-area, and ribs are in the area that ultimately in reptiles, birds and mammals becomes the neck. Fish are neckless, a state which is marked by ribs extending to the head. Fish are propelled by the thrust of the tail and this force is transmitted through the body mainly by the vertebrae, but the ribs serve to stiffen the body and thus to prevent loss of propelling power.

The neck is formed by the passage of the pectoral girdle, which strips the neck-area of its ribs; or, to be more exact, the passage of the girdle is associated with the denudation of the neck of its rib tissue. From the fact that fish are neckless, and that limbed vertebrates have necks, it is apparent that the evolution of the neck becomes necessary as the limbs are evolved. A neck is of no use to a fish and a formed neck in marine animals has the effect of diminishing speed and making steering difficult. As the limbs were evolved they descended the neck, and as they descended they became larger and stronger, and as the limbs became larger and stronger the neck proportionately developed. The pectoral girdle provided the means whereby the fore-limbs were carried down the neck, and with them the heart, from the gill-area to the thorax, these migrations becoming necessary as more perfect land progression was essential to the

animal. As the girdle passed down the neck, the cervical vertebrae were denuded of their ribs, to a greater or less extent, according to the activity of the neck movements.

The fore-limbs of *Ceratodus*, the lung-fish of Queensland, though only slightly developed, are somewhat larger than the fore-limbs of pectoral fins of ordinary fish. It seems most probable that the slight increase in size of these puny fore-limbs is the result of impulses that have resulted from contact with mud. Ribs are present in the neck area and throughout the remainder of the body cavity.

The *Menopome*, which Owen describes on page 48, vol. I. of the 1866 edition of Comparative Anatomy, shows some limb and neck development. Small ribs occur throughout the body and neck of this amphibian.

*Trachysaurus rugosus*, compared with *Ceratodus*, shows a great development of the pectoral girdle, a development which expresses the construction of a bony carriage that is used to convey not only the fore-limbs down the neck as they progressively develop, but also the heart from a position of threatened danger to one of secured safety, that is from the throat to the chest. In this lizard the pectoral girdle embraces the heart in what corresponds to the gill-area, beneath the neck, and spreads itself over and above the cervical ribs. As the pectoral girdle bears the heart and fore-limbs down the neck, the cervical ribs are reduced to rib-stumps, a condition that is remarkably well shown in the crocodile. *Trachysaurus* has poor powers of progression, its limbs being small and its neck undeveloped. It is an interesting animal because it shows the early stages of the migration of the heart from the gill-area to the thorax, during which migration the left recurrent laryngeal nerve is caught about the aorta and dragged into the thorax.

The Tuatara lizard, *Sphenodon punctatus*, shows partial suppression of the ribs of its neck, therein agreeing with that rib suppression which is seen in the more common lizard.

*Varanus varius* is as active a lizard as *Trachysaurus rugosus* is sluggish. It has a long neck containing six cervical vertebrae; its heart has left the pectoral girdle and become an occupant of the thorax, and its pectoral girdle shows signs of atrophy. In the crocodile the pectoral girdle undergoes further atrophy, and the posterior portion is retained to form the coracoid bones. The narrowing which the girdle undergoes, in being transformed into the coracoids, enables the seventh vertebra to perform neck movements; and thus the seven cervical vertebrae that characterise the mammalian neck, are established.

This is a critical time in the evolution of the mammalian neck, for at this stage the body is elevated for raised quadrupedal pro-

gression. The impulses that accomplish this great change etch into the mammalian neck its very fixed characters.

The neck of the crocodile bears fourteen cervical rib-stumps, made up of seven pairs;-the first and second pairs are long because the pectoral girdle only caught their tips in its span of the ventral and lateral aspects of the neck. The neck of *Varanus* bears less rib tissue than the crocodile, and this difference expresses the greater movement of the neck that the *Varanus* exercises in comparison with the crocodile.

According to the activity of the neck movements, the denudation of the cervical ribs that occurs as the pectoral girdle passes down the neck, is more or less complete. The stiffness of ribs in the neck prevents free neck movement. The cervical ribs stiffen the neck, therefore those impulses that set up active neck movements in association with limb progression are destructive to cervical ribs.

## Coracoid Bones.

These bones maintain the fore-limbs on the lateral aspects of the body in positions that are favourable for swimming and for flight, therefore they occur in amphibians, reptiles and birds. As the body was lifted for mammalian quadrupedal progression, the lateral position of the fore-limbs gave place to the ventral position, and the space occupied by the coracoid bones became needed, and was later occupied by the limbs. In the impulses that established raised quadrupedal progression, destructive hostility to the coracoid bones existed and the coracoids are now to be seen as vestiges on the mammalian scapula.

Vestiges are often referred to as being capable of development, and in this connection it may be pointed out that the flying-fox, fox-bat of *Pteropus*, a mammal that has acquired the ability to make sustained flight, has not redeveloped its coracoids.

The coracoid bones of birds and reptiles cross the sternal ends of the first ribs, and to avoid collision of bone with bone, the sternal ends of the ribs are fibrous. In this connection it is to be noted that Keen, in the American Journal of Medical Science, shows a plate of a human cervical rib that had a very definite fibrous end. The significance of Sibson's fascia remains to be explained: a careful investigation of this structure is likely to establish between cervical rib development and Sibson's fascia a close relationship, for it seems probable that this fascia is the forerunner of a cervical rib.

The fibrous nature of the sternal ends of the first ribs in reptiles and birds lends a yielding character to the junction of neck and chest, whereas the bony first ribs of mammals give a rigidity to the

boundary between neck and thorax. In many birds and many reptiles the coracoid bones migrate backwards and establish eight and more neck bones, and as they go back they imperil rib-end after rib-end, which becomes removed by the associated impulses. In this way the long necks of birds and reptiles are apparently formed.

Extinct Sea Lizards.—The *Ichthyosaurus* had cervical ribs. The *Plesiosaurus* had a long neck and no ribs on the first seven bones; it may be inferred that *Plesiosaurus* was slower in the water than the *Ichthyosaurus*, and that it first developed its long neck on swampy land, after which it became aquatic.

Elevated Quadrupedal Reptiles.—The *Brontosaurus* had both a long neck and tail, each of which contained many vertebrae. It had attained a mode of progression that has some resemblance to mammalian quadrupedal progression. It would seem that these extinct reptiles were not lifted from the ground by their limbs when seven neck bones had been formed, and that body elevation in their case only occurred after many neck bones had already been established.

Fixed Mammalian Neck-type.—This is characterised by seven neck bones devoid of cervical ribs, associated with a definite type of neck curvature that is more or less marked. This type was established by the mammalian body being lifted up from the ground by the limbs when seven neck bones had been formed, an event that was accompanied by the suppression of the coracoid bones.

Monotremes.—The monotremes show neck structures transitory between reptilian and mammalian type; the platypus, that lives mostly in the water, has relatively larger coracoid bones than the echidna, that lives on land and mostly in soil. It would seem that the approximation of the limbs to the ventral aspect to allow of burrowing operations has been inimical to the coracoids. The echidna has better fore-limb development and greater neck curvature than the platypus. The straighter neck of the platypus contains cervical rib-stumps, whereas the rib tissue in the curved neck of the echidna is less of the nature of rib-stumps and more of the nature of costal processes.

The echidna shows rib-stumps merging into costal processes; therefore the suppression of ribs into costal processes can be traced, but I am unable to find evidence supporting the prevalent idea that costal processes develop into cervical ribs, the term "costal process" being taken as synonymous with vestigial ribs and not with the costal rudiment. The echidna shows that under the impulses that raise the body from the ground the curvature of the neck becomes established, and the rib-stumps disappear into the costal processes.

The first ribs of the monotremes differ from those of reptiles in being attached to the sternum by bone; they differ from mammals

with which they are classed, in having between the sternal rib and the true rib an intermediate rib. The first ribs of monotremes are more rigid than the first ribs of reptiles, but they are less rigid than the first ribs of mammals. In this connection it may be pointed out that in ruminants a diathrodial joint occurs between the ribs and the sterna cartilages, which joint does not upset the fixed neck type, but it serves to illustrate the fact that impulses may determine the formation of joints in parts of the body in which joints do not usually occur.

Neck curvature is practically absent from lizards and crocodiles: it is slightly marked in the platypus, and more so in the echidna; it reaches its highest development in the mammals, such as llamas and antelopes. The neck curves of birds do not occur in definite places as they do in mammals, these definite neck curves being due to the weight-carrying qualities and length of the fore-limbs, and also to the length of the neck. The neck must be of sufficient length to enable the animal to gather its food.

The weight of the head suspended at the end of the neck has set up impulses that have developed the ligamentum nuchae to conserve the muscle energy of the muscles of the neck. The elastic ligament always exerts its force in definite directions, and it is a prominent factor in producing the definite neck curves of mammals. In man the ligamentum nuchae is poorly developed, and his neck curves are practically lost.

When it is remembered that fish and snakes have cervical ribs, that the crocodile has seven pairs of rib-stumps, that the *Varanus* is almost without rib tissue, and that quadrupedal mammals are entirely free from cervical ribs (except vestiges), it becomes apparent that neck mobility, when associated with quadrupedal progression, is hostile to neck ribs.

No quadrupedal mammal normally has cervical ribs. No mammal that habitually carries part of its body weight on the pectoral limbs varies from seven neck bones. All mammalian cervical ribs and all mammalian variations from seven cervical vertebrae, occur amongst those mammals that have abandoned quadrupedal progression, such as *Bradypus*, *Porpoise*, *Manatee*, *Dugong* and *Man*.

Quadrupedal mammals remain true to neck type because they perform those neck and limb functions which the mammals were evolved to perform. Mammals that have abandoned quadrupedal progression may show destruction of the fixed mammalian neck type, but all such animals do not vary from fixed type. Those that are variant have been submitted to impulses of a hostile nature; great stability of type occurs when the neck has to operate from a thorax that has been made rigid by the impulses that are associated with

supporting the weight of the body above ground; and conversely, the type is less fixed when the thorax is not made rigid by such impulses. In the quadrupedal mammals, the transmission of the weight of the body from the sides of the ribs through the great serrated muscles to the scapulae, and thence through the limbs to the ground, narrows the cephalic end of the thorax by lateral pressure; this narrowing of the thorax, which is splendidly shown in the skeletons of the horse and giraffe, drives the lungs towards the loins and keeps the apices of the lungs behind the anterior border of the first ribs.

The apices of the lungs above the first ribs, the normal anatomical position in man, constitutes a divergence from the normal mammalian position of lung. Ribs unaffected by pressure are curved, probably because between curved ribs the maximum amount of lung may collect. Be that as it may, the fact stands that the first ribs are the most curved ribs in the human body, and that the first ribs of the horse are the straightest in its body. The first ribs of men are practically never fractured, because no strain is thrown on them; the first ribs of the horse are frequently fractured by the strain thrown on them by the weight of the horse's body, and also by the load superimposed by man. The bearing of these facts on cervical ribs is that straight first ribs prevent the lung passing into the neck, whereas curved first ribs permit the passage of the apices of the lungs into the neck, and when lungs gain the mammalian neck, ribs develop over them as the occupation of the neck becomes more extensive.

Marsupials.—All these animals, including the extinct *Diprotodon australis*, are true to mammalian neck type. The kangaroos have acquired a mode of progression that has led to atrophy, from disuse of the pectoral limbs and upper thorax. Owing to the inclination of the body being submitted to great changes, a good degree of neck curvature exists; mostly the body is tilted downwards and forwards, and it is erect for only brief periods; thus the lungs occupy the position that is normal to quadrupedal mammals, and they are not induced to migrate, as they do in man, towards the neck.

The lungs of the kangaroo do not encroach upon the neck, therefore cervical ribs do not occur in these animals.

Xenarthra.—The neck structures of the animals of this order afford an interesting and difficult study, interesting because of the variation of type that occurs in the sloths, difficult because abundant material for comparison is hard to get.

The extinct *Megatherium* was true to type, and therefore it is probable that all the animals belonging to this order were originally of ordinary mammalian type.

The dermal armour of the *Armadillo* has prevented movement between the bones of the middle of the neck, and they are fused into a rod of bone; this fact suggests that as the necessity for joints departs, they disappear.

*Bradypus*, or three-toed sloth, has been compelled to lengthen its neck to afford the head a wider range of browsing circumference. As a result of the impulses generated by its hanging and browsing habits, the first and second thoracic vertebrae have lost their ribs, and thereby these back bones have been converted into neck bones. The animal spends its life hanging body downwards from the branches of trees, and under the impulses resulting from this mode of life, the fixed mammalian type has been broken down, and the rigidity of the anterior thorax has given place to adaptations that have extended the movements of the neck to the thoracic region. In this mammal it is observed that under the necessity for elongating the neck the first and second thoracic vertebrae are added to the neck, which is not according to the mammalian rule. The giraffe has elongated its neck, but it has done so under the control of a strictly quadrupedal gait and consequently its neck is composed of seven cervical vertebra, according to the law which holds the mammalian neck true to type. The three-toed sloth, therefore, shows destruction of the fixed mammalian type, and therefore conclusively proves that fixed type must, when impulses change and assail its fixed characters, yield up its stability, become plastic and change into aberrant type. This fact shows that the law of evolution, like the law of gravity, is ever operative: the evidence which the three-toed sloth offers in this direction is augmented by every mammal that has changed from the fixed mammalian type.

Choloepus.—There is considerable diversity of opinion as to the number of neck bones that are in the neck of the two-toed sloth. Owen describes seven bones, Thomson six, and Wiedersheim writes thus of the ribs of mammals:—"The cervical ribs in nearly all cases unite completely with the vertebrae, and a vertebrarterial canal is thus formed. The last cervical rib may be well developed and may articulate with the corresponding vertebra (*Choloepus Hofmanii*)."

This diversity of opinion may be due to the different species of two-toed sloths varying from one another, as do the two genera of the order *Sirenia*, or to variations within the species itself, as occurs in man.

The three-toed sloth has a short, thick body which is suspended by short, thick limbs; the body is too short to sag in the middle of the back, and it consequently hangs straight in the horizontal. The two-toed sloths have long, narrow bodies and long limbs, and when suspended in what would produce a horizontal position in the three-

toed sloth, the animal presents a long U, with the middle of the back at the lowest part, and the head in a position that is more or less erect. The two-toed sloth has a body and limbs that are long and lithe enough to gather its food without the neck elongation that has occurred in the three-toed sloth, and in its peculiar position, together with the fact that it has abandoned quadrupedal gait, it would not be surprising if dissection should reveal that its lung has risen into the neck and cervical ribs have formed.

The three-toed sloth is said by Wiedersheim to have cervical ribs upon the seventh neck bone. A skeleton of this animal in the Melbourne Museum does not show them, and Owen, who went very carefully into the question, only depicts rib-stumps on the eighth and ninth bones. But it is not surprising that Wiedersheim has found cervical rib structure in the three-toed sloth. In the normal mammals, costal processes are absent from the seventh bone, and this permits flexion of the neck on the chest, an extensive movement where neck curvature is great. As the *Bradypus*, by its peculiar gait, abolished the curvature of its neck, it may have become necessary to stiffen up the seventh bone to harmonise it with the sixth above and the eighth below, so that the neck may be of proper strength in its various parts.

Clavicles and Flight.—The *Pteropus* or flying-fox, or fox-bat, is a mammal that has acquired the power to fly, yet its neck type is true to mammalian characteristics. This stability of type appears to be due to several causes: this animal walks on the ground in quadrupedal fashion, and not after the manner of birds, on the pelvic limbs: and in developing its air-planes it has had to do without the great help that birds derive from the coracoid bones, consequently those changes that occur in birds through the presence of the coracoid bones, are not to be seen in the flying-fox. Although the clavicles of the flying-fox are greatly developed, they can do no more than partly compensate for the absence of the coracoids, because the position of the clavicle is anterior and external to the central and interior position which the coracoids, if present, would occupy. The clavicles play no part in the formation of cervical ribs, but by holding the scapula off the thorax, they afford the arm the means of executing a wider range of rotary movement.

If vestigial structures possess the ability to come back to functional activity, the coracoid processes of this flying mammal should re-establish the coracoid bones; instead of that, the clavicle, by over-development, throws the pectoral limbs from the ventral to the lateral thoracic position. The coracoid process remains unaffected in spite of the demands that flight makes upon coracoid bones. If

atavism were a real thing in relation to ribs and other bones, the flying-fox should have coracoid bones.

Marine Mammals.—The New Zealand dolphin has had the bones of its neck fused into a short, solid mass by impulses engendered by the impact of water on the head, which is driven against the water by the force exerted by the tail. This animal does not emerge from the sea, and consequently it has entirely abandoned quadrupedal gait. The mammalian character of its neck has been destroyed by the fish-like impulses that its acquired habits have set up. The *Susue* has seven flattened neck bones that occupy very little space. On the second, third, fourth, fifth and sixth cervical vertebrae the costal processes are widely separated from the transverse processes; on the seventh there are no costal processes, but the head of the first rib articulates with the body of the seventh vertebra, and its tubercle with the transverse process of the first thoracic vertebra. A similar arrangement to this occurs in the Beluga Whale.

Seals, sea-lions and walruses form an interesting class of sea mammals. Their necks are long, and they are true to mammalian neck type, and this is due to these animals using their fore-limbs to lift themselves out of the water, and also to their habit of travelling over the rocks after the manner of quadrupeds.

At the end of the long neck of the seal are well-developed fore-limbs. At the end of the shortened neck of the New Zealand dolphin is an atrophic pair of fore-limbs. This association of structure suggests that as the limbs descended the neck, during the evolution of limb progression, a gradual increase in the size of the limbs took place; and as the limbs recede up the neck, as quadrupedal progression is abandoned, and the upper part of the pectoral limb is progressively less used, the limbs progressively become smaller as they approach nearer and nearer to the head. Thus not only can the evolution of the neck be studied, but it is also possible to study the involution of the neck.

The seals demonstrate more plainly than any other mammals the effect of quadrupedal progression on structure; for there can be no doubt that the long neck of the seal handicaps its progress through the water, though the neck is retained for the functions it performs on the land.

The order *Sirenia* offers a valuable mass of material bearing on cervical ribs. The following quotations are from Flower's Osteology of Mammalia, 1885, p. 42:—

"In the order Sirenia the Dugong (Halicore) has seven cervical vertebrae."

"The Rhytina, a large animal of this order, which became extinct towards the close of last century, has also seven cervical vertebrae, and the Miocene halitherium had also the same number."

"The Manatees (genus Manatus), of which there are two well-known forms, one inhabiting the West Coast of Africa, and the other the East Coast of Central and South America, never have more than six vertebrae in the cervical region."

"In a specimen of the Manatus senegalensis, in the Museum of the College of Surgeons, the second and third are ankylosed by their bodies. In the skeleton of M. Americanus, in the Museum of Cambridge, the sixth cervical vertebrae carries a distinct moveable rib."

Flower does not explain why only six bones occur in the neck of the manatee, but it is quite clear that the details he describes point most strongly to the fact that the normal seventh cervical vertebrae of mammalia has in the manatee developed a pair of perfect cervical ribs.

The evidence in support of this is open to no other interpretation, especially in face of the fact that the specimen at Cambridge has extended the rib-forming process as far as the sixth bone, and also in face of the added fact that the specimen of the manatee in the Melbourne Museum shows upon the body of the six vertebra demifacets for the head of the rib that rests in an articulation formed by the sixth and seventh bones. It also seems that as the miocene *Halitherium* was true to mammalian type, the manatees have acquired the change to the six neck bones.

The *Dugong* occupies a variable position in regard to cervical ribs; usually this animal is without cervical ribs; the specimen in the Melbourne Museum has a pair of short cervical ribs upon the seventh cervical vertebra; they are about two inches long, and they form movable articulations. All the bones of the neck of the dugong are flattened, and they are not fused by ankylosis.

It is not as easy to ascertain the cause of the development of cervical ribs in manatees and dugongs as it is in man, for in these animals it is necessary to consider two possible causes, and then to determine which is the causative factor. It is therefore necessary to discuss whether the manatee develops its cervical ribs to stiffen its neck area, as fish structure suggests, or whether the cervical ribs of the sirens develop for respiratory purposes. If material could be readily procured for dissection, the matter could easily be cleared up, but even at Port Darwin a specimen of a dugong for investigation is most difficult to procure. If the manatee required a stiffer neck than it has, impulses would probably set up an ankylosis such as that which exists in the porpoise; the ankylosis that is already established between the second and third bones, places it beyond doubt that the manatee can, under suitable impulses, set up ankylosis of its neck bones.

It is unlikely that the manatee uses two means to stiffen its neck, ankylosis and cervical rib formation, when by ankylosis alone the

porpoise has produced a much stiffer neck than the manatee. The ankylosing process is all-sufficient for stiffening purposes. The ribs that develop on the seventh vertebra of the manatee are perfect sternal ribs, and they bear every evidence of being respiratory ribs.

The impaction and ankylosis of the neck bones of the porpoise has carried ts head towards its lungs, and the formation of cervical ribs has carried the thorax of the manatee nearer the head. Marine animals derive some advantage by the lungs being near the head, for there, by buoyancy, they assist the nostrils to come to the surface when the oxygen supply has been used up beneath the water.

It appears that cervical ribs develop in manatees and dugongs in association with the lungs, and that the need for the stiffening effect of ribs upon the neck, as an aid to water progression, may be ignored as a causative factor in the development of cervical ribs.

It is difficult to ascertain the rate of speed at which these slow-moving sirens travel, but as the fast-moving porpoises exhibit impacted necks, it may be inferred that the greater the speed, the greater the impaction of the neck. When the neck is ankylosed, as the result of impaction, it is, for all practical purposes, reduced to a condition that functionally corresponds to the neck area of fish. Under the sluggish movements that are executed by the dugong, the force that is set up by the action of the tail muscles, and which is resisted by the water, is mainly transmitted through the bones of the spine, and it is not great enough to impact the cervical vertebrae and its effect on the bones is shown only by their flattened state.

It appears from the study of mammalian neck bones that water pressure, in the absence of quadrupedal progression on land, is a great destroyer of fixed mammalian neck-type, but that even these extremely hostile neck impulses are insufficient to destroy mammalian neck-type when use is made on rock and ice of the fore-limbs for supporting the weight of the body.

## Mammalian Quadrupedal Progression.

All mammals that go on four limbs are not equally developed in the fore and hind limbs, and there are many degrees of quadrupedality. The most perfect quadruped is the horse; its limbs are entirely devoted to progression and supporting body weight; therefore its neck type is fixed and cervical ribs are unknown in these animals.

Animals that have the power of standing for long periods have narrow chests; a narrow chest is a good point in a horse, and great transverse measurement is the mark of an underbred or slow animal. The full pectoral region that is so admired in soldiers has its counterpart in the flying-fox. Narrowness of the cephalic end of the thorax

serves to keep the lungs within the thorax and to prevent them migrating to the neck.

From the quadrupedal baboon through the semi-erect apes to erect man, a progressive comparative decrease in the relative size of the fore-limb to the hind-limb is to be observed. In other words, man's arms are small compared with his legs; the fore-limbs of the baboon are larger than its hind-limbs. The baboon shows on its thorax the effect of bearing the weight of the body. The neck of the elephant is compressed by the weight of its head, the neck of swine by rooting, the neck of man by his head weight. Compression of the neck destroys the neck curves and curtails neck mobility. In man the neck curves have been obliterated, and the first ribs have become fully curved. From these two causes the lung is permitted to rise in the neck as the erect position has sunk the heart in the thorax and displaced the lung upward. Lung in the neck has set up impulses that cause cervical ribs to develop. Such development has occurred in relation to the disappearance of progressive and other active uses of the shoulders and arms of the upper limbs, and this fact explains why cervical ribs are three times as common in women as they are in men.

As quadrupedal progression has been abandoned by all mammals that have cervical ribs, and no quadrupedal mammal has cervical ribs, it may be assumed that the crawling period of infancy is the great factor that keeps the human neck true to type, or approximately true to type; for since the neck of seals keeps true to type, although its fixed type is challenged every time it swims with its head beneath the surface, a very moderate amount of quadrupedal exercise is evidently sufficient to keep the neck true to type.

## The Unstable State which follows the Destruction of the Mammalian Neck-type by Erect Bipedal Progression.

The migration of the lung towards the neck has led to a mass of lung tissue being piled above the heart, and to an atrophy of the lower thorax, hence the diaphragmatic base of the human lung is small in comparison with the phrenic base of the quadrupedal mammalian lung. As the functions of the lower thorax of man have been transferred to the upper thorax, diaphragmatic breathing has become less perfect, and costal breathing has begun to show up. This change has been caused by the erect position. The lightest organs in the thorax rise to the top, which top, in man, is the widened space between the first pair of ribs; the sinking of the heavy heart

displaces the lighter lung upward; this sinking is evident from the fact that the pericardium in man has a more extensive attachment to the diaphragm than it has in any other animal, and also by the aorta having a longer arch.

Arthur Keith, in his work on "The Mechanism of Respiration in Man," on page 187 of "Further Advances in Physiology," edited by Leonard Hill, 1909, draws attention to the observation of Colbeck that during inspiration the apices of the lungs recede from the neck. In a rough way this observation can be confirmed by making forced inspiration in the front of a mirror and there watching the dimpling of skin in the neck that takes place with each inspiration. On page 200 of the same book Keith refers to the observation of Wenckebach, "In subjects of extreme visceroptosis, the diaphragm is thrown out of action by its visceral fulcrum being lost, and breathing is carried on by an elevation to the upper part of the thorax." This important observation shows as plainly as does the effect of tight corset lacing, that curtailment of the action of the diaphragm is compensated by costal breathing, and there can be no doubt that the diaphragm is a more efficient muscle of inspiration than the upper intercostal muscles.

As the encroachment of the lungs into the neck is the cause of the development of cervical ribs, it follows that full curvature of the upper ribs and loss of the curves of the neck are changes that prepare the way for the apices of the lungs to pass through the space between the first ribs, and consequently such changes are co-operating factors in the production of cervical ribs.

In man the costal development that is associated with the seventh cervical vertebra ranges through all grades from the quadrupedal type to fully formed cervical ribs. In other words, the seventh cervical vertebra of man may show:—

(1) The absence of costal processes (extinct ribs).
(2) Costal processes (vestigial ribs).
(3) Cervical ribs in various stages of development.

Far reaching as these changes are, they do not include all variations, for unequal development of the two sides of the seventh cervical vertebra is by no means uncommon.

The quadrupedal baboon is, like other quadrupeds, devoid of costal processes, and therefore it is probable that during the stage of quadrupedal progression of the human race the seventh vertebra of man was constantly without costal processes; in other words, these ribs were extinct.

The gorillas in the Melbourne Museum are without costal processes on the seventh vertebra. An orang, in the same museum, is also without them. One chimpanzee is without costal processes, another has them. Of the skeletons of apes in the Melbourne Museum only

one has costal processes on the seventh cervical vertebra—a small chimpanzee.

The causes that determine the development of cervical ribs appear to be:—

(1) Disuse of the upper limbs for the purpose for which they were developed, viz., quadrupedal progression. The removal of the weight of the body from the sides of the ribs has allowed the first and upper ribs to become curved, and thus an increased space has been afforded through which the lung has migrated, hernia fashion, into the neck.

(2) Hostile impulses assailing the established mammalian neck type; the chief of these arise from the presence of lung in the neck. Nowhere amongst the mammals are jointed ribs seen except in association with lung and the function of respiration.

The following changes have occurred in the human neck:—

(1) The bodies of the neck bones have been flattened by the weight of the head, and thereby the neck has lost mobility.

(2) The erect position has caused the neck curves to be reduced and the neck and chest to be brought into more direct line.

## Lateral Curvature of the Spine (Scoliosis).

This condition is so extremely rare in quadrupedal mammals that it may be said not to occur in such animals. In man lateral curvature is common, and, associated with cervical ribs, lateral curvature may be said to be the rule. The surgical treatment of cervical ribs is inseparable from a careful consideration of the part played by lateral curvature. In the review of the necks of seals and porpoises, it has been seen that disuse of the fore-limbs for progression on land is accompanied by a profound atrophy of the pectoral limbs. The term involution of the neck may be applied to this atrophic condition. The arms of Man that are associated with cervical ribs are in a state of atrophy, and they have receded towards the head by the distance occupied by the cervical ribs. It will be remembered that the fore-limbs of the slowly moving lizards are near the head, in other words in the early evolution of the neck the fore-limbs are near the head. Surgeons have repeatedly recorded that cervical ribs shut off by pressure the arterial blood supply of the upper limbs, and Keen shows an artery that is much larger in lumen on the proximal than on the distal side of the cervical rib over which it passes. Anatomy abounds with evidence that during development arteries mould bone to their service. Bones support and protect the more delicate tissues of the body, even the delicate convolutions of the brain leave their indented

impressions on the hard inner tables of the clavarium. The reason that cervical ribs appear to strangulate the blood supply of the limbs is that from the involuted limbs no impulses arise to put into the heart and artery enough force to drive blood in greater quantity to the involuted limbs than their atrophic state demands. If the development of cervical ribs occurred with big and vigorous pectoral limbs, there would be force enough in the artery to groove the ribs and to accommodate itself so that the blood supply would be unimpeded.

The treatment of cervical rib is confronted by greater difficulties than a piece of bone: cervical rib is but the index of an undesirable evolutionary condition which Oppenheim calls "stigmata of degeneration." Some of the results of the abandonment of quadrupedal progression are:—

(1) Weak upper limbs.
(2) Atrophy of the neck.
(3) Costal breathing.
(4) Migrated lung.
(5) Depressed heart.
(6) Liability to brain injury through curtailment of neck mobility.

The practical side of the subject of cervical ribs divides itself into two sections:—

(1) The treatment of those suffering from the conditions that are associated with neck ribs. (This is work belonging to experienced surgeons.)
(2) The physical training of the human body so that the existing occasional tendency to develop cervical ribs may be turned into a tendency to remain true to normal neck-type.

The crawling period of infancy is probably the great factor keeping the human neck, arms and thorax true, or approximately true, to mammalian type; therefore games of a quadrupedal nature are beneficial to children. Growing children should be examined periodically for the detection of any tendency to lateral curvature of the spine. Exercises for the development of the great serrated muscles should during the period of growth and development, be taken daily. During childhood, adolescence and adult life, diaphragmatic breathing should be regularly practised. Adults starting to take exercises should remember that there are two types of neck, (1) the normal or mammalian; (2) the aberrant type in which cervical ribs occur.

The exercises that have been advocated are of the nature of a return to natural function which the erect position has thrown out of use. It should be clearly borne in mind that those adults who have cervical ribs are likely to cause themselves pain by doing quadrupedal exercises, as their evolved tissues are ill-fitted for such work.

## Summary.

The mammalian neck was evolved to co-ordinate its movements with those of the fore-limbs during elevated quadrupedal progression. Elevated quadrupedal progression caused the mammalian to become the most fixed type amongst necks. The mammalian neck remains fixed to type so long as the functions which compel its evolutions remain constant. The mammalian neck remains true to type after its functions have been abandoned until such times as it becomes assailed by hostile impulses. Cervical ribs in the mammalian neck express the breaking down of fixed mammalian neck-type.

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